Edited by Bill Travis and Anne Watson Swager

Simple circuits provide nonlinearity

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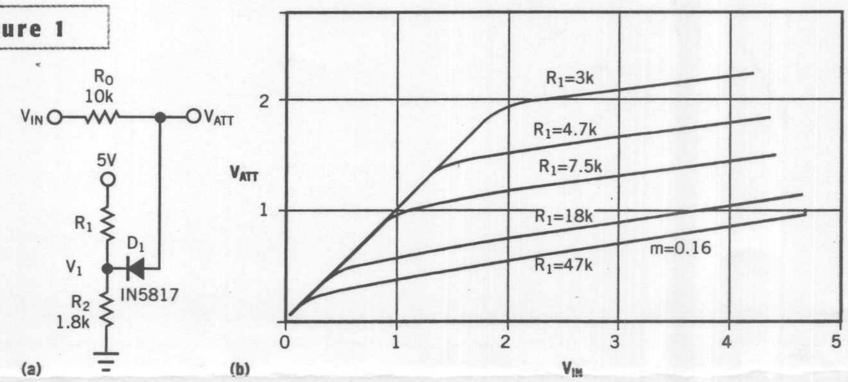
IN ANALOG DESIGN, you might need to create an amplifier with nonlinear dynamic characteristics—for example, logarithmic, exponential, or square-law. Usually, such amplifiers are complicated. However, the project often does not require mathematical precision. For example, you might just need to increase the dynamic range of an amplifier, or to eliminate saturation for an extended input-voltage range. The Design Idea is based on the nonlinear voltage attenuator with the attenuation ratio $m=V_{ATT}/V_{IN}$, controlled by the input voltage (**Figure 1a**). When V_{IN} is small enough to hold off D_1, $m=1$. When the input voltage increases and attains a certain threshold voltage, V_{TH}, the diode conducts, and the attenuation ratio decreases. The new value of m depends on the values of R_0 and R_2. R_1 and R_2 determine the threshold level, V_{TH}. Hence, you can estimate the resistors R_1 and R_2 for a given R_0, V_{TH}, and m as: where V_D is the drop across diode D_1, and V_R is the dc voltage applied to R_1 and R_2.

$$R_2 = R_0\frac{m}{1-m};$$

Figure 1

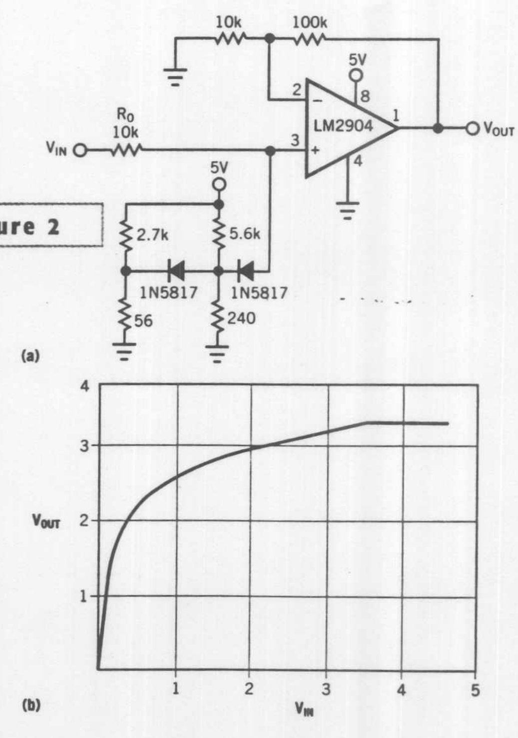


Manipulating the resistor values in an attenuator (a) changes the threshold for nonlinearity (b).

$$R_1 = R_0\left(\frac{V_R}{V_{TH}-V_D}-1\right),$$

Note that you can create any characteristic by choosing the proper ratio, m, and the threshold voltage for each fragment of the resulting characteristic. Also, the linear approximation is good for calculation purposes, but the real ratio changes smoothly near the threshold voltage. Finally, use Schottky diodes to increase the voltage range of regulation. **Figure 1b** shows the dynamic response of the attenuator for the constant ratio $m=0.16$ but for different threshold voltages. The measured voltage is $V_1=V_{TH}-V_D$. To increase the dynamic range of an amplifier, you should put the nonlinear attenuator at the input of the amplifier. To

Figure 2



A multistage nonlinear attenuator (a) can increase the dynamic range of an amplifier (b).

widen the range, you can use a two-stage attenuator. **Figure 2** shows such an amplifier and its recorded characteristic. The applications of the nonlinear attenuator are not limited to increasing dynamic range. You can obtain a square-law response, for example, by putting the attenuator in a feedback circuit (**Figure 3**).

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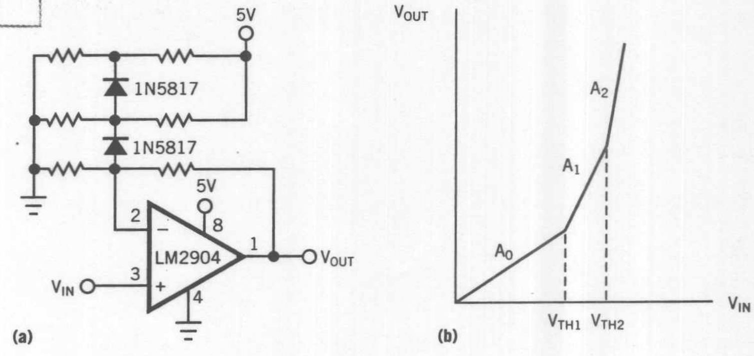
Figure 3



A nonlinear attenuator in the feedback loop (a) results in a square-law characteristic (b).

Regulator IC forms convenient overvoltage detector

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FIGURE 1 SHOWS A simple, standalone overvoltage detector. The intent of the circuit is to monitor a voltage, $V_{MONITOR}$, and set the output, V_{OUT}, high when the monitored voltage exceeds a preset threshold. The minimum allowable threshold for this circuit is 1.25V. The operation of the circuit revolves around the TLV431 shunt regulator. This IC is based on the popular TL431 shunt regulator. The difference is that the TLV431's internal reference is 1.25V, as opposed to 2.5V for the TL431. When the voltage at the control input is less than 1.25V, the regulator's cathode current is essentially zero. If the control input exceeds 1.25V, the cathode conducts and turns Q_1 on to produce a high output at V_{OUT}. The trip threshold, determined by resistors R_1 and R_2, is $V_{THRESHOLD}=1.25(1+R_1/R_2)$. D_1, the diode between V_{OUT} and the control input, provides hysteresis and latches the overvoltage fault condition. If you don't need latching operation, you can add a resistor in series with the diode to lower the hysteresis value and prevent the circuit from latching.

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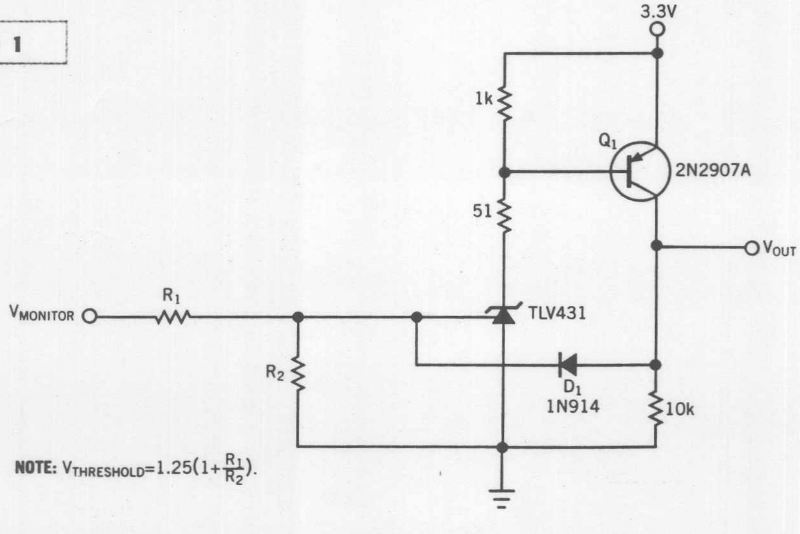
Figure 1



NOTE: $V_{THRESHOLD}=1.25(1+\frac{R_1}{R_2})$.

A shunt regulator makes an inexpensive overvoltage detector.